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Materiel Test Procedure 6-2-334
Electronic Proving Ground

U. S. ARMY TEST AND EVALUATION COMMAND
COMMODITY ENGINEERING TEST PROCEDURE

3670

SURVEY SYSTEMS, AIRBORNE

1. OBJECTIVE

The objective of this materiel test procedure is to describe the engineering tests required to determine the technical performance, engineering adequacy, and technical characteristics of airborne survey systems relative to the requirements of applicable Qualitative Materiel Requirements (QMR's), Small Development Requirements (SDR's), Technical Characteristics (TC's), or other applicable requirements and documentation, and determining their suitability for an intended use.

2. BACKGROUND

Airborne survey systems in use or under development by the Army permit accurate surveying under conditions which would not permit the use of any other method or would require excessive time and manpower. Bodies of water can be crossed and surveys extended across land masses impenetrable or difficult of access to ground survey parties.

Airborne survey systems may be broadly classified by the scope of the survey requirements, i.e.

- purpose, strategic or tactical
- earth surface area of interest, size, condition, and number of points to be identified
- order of accuracy
- urgency for final data

In the context of this MTP, two generic systems are considered, (1) a geodetic survey type system capable of covering large areas with a high order of accuracy in strategic situations and (2) a position-determining type system for use in tactical situations to establish survey control points on the ground by XYZ map coordinates where time is of the essence and a lower order of accuracy can be tolerated, e.g. artillery fourth or fifth order.

A typical geodetic survey system employs radio-ranging techniques and incorporates an airborne interrogator-distance measuring set and several compatible transponder sets located at known geographical positions. With the aircraft operating on planned flight paths relative to the ground stations, the airborne set sequentially interrogates the transponders and transmits and receives ranging signals. The position of points on the earth's surface directly beneath the aircraft are continuously computed from the measured slant range to each ground station and recorded in conjunction with simultaneous aerial photography for conversion to precise geodetic data.

A tactical airborne survey system is normally employed in rotary-wing aircraft due to the inherent advantages of slow speed, low altitude and the hovering capability. One such system, termed a position- and azimuth-determining system is somewhat comparable to a land navigation system wherein the vehicle's course from a known starting point is continuously computed and displayed on a scaled and gridded map from system inputs of ground speed and direction changes, the latter referenced to a gyrocompass. The airborne system incorporates the additional feature of terrain elevation determination (Z coordinate) by means of an absolute altimeter which is pre-set at the known starting-point elevation above mean sea level.

Engineering tests of airborne survey systems are required to determine the extent to which the equipment meets the prescribed technical performance and safety characteristics, and to provide data for use in further development.

3. REQUIRED EQUIPMENT

a. Meteorological Support Facility
b. Automatic Data Processing Facility (Including autograph)
c. Photoprocessing Facilities
d. Surveyed flight test area providing:

    1) over water flight path
    2) line crossing flight paths

e. Surveyed land test area
f. Test bed aircraft containing:

    1) airborne profile recorder
    2) aircraft photographic mapping subsystem
    3) meteorological equipment

g. Test bed land vehicle
h. Ground Station, Geodetic, Radio Ranging subsystems
i. Survey instrumentation

4. REFERENCES

A. Aslakson, Carl I., Fickeissen, O. O., The Effects of Meteorological Conditions on the Measurement of Long Distances by Electronics, Transactions, American Geophysical Union, Vol. 31, No. 6, pp. 816-826, December 1950.
B. Engineering Evaluation of the RC-130-A Aircraft Electronic Surveying and Photographic Systems, Lockheed Aircraft Corporation, Contract AF 33 (600)-3357, 15 April 1960.
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D. HIRAN Surveying Handbook, 1370th Photomapping Squadron, April 1954.
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G. FM 1-105, Army Aviation Techniques and Procedures.
H. FM 6-2, Artillery Survey.
I. TM 5-441, Surveying, Topographic, Methods, Procedures, Instruments, etc.

5. SCOPE

5.1 SUMMARY

5.1.1 Technical Characteristics

The procedures outlined in this MTP provide a methodology for empirically determining the technical performance and characteristics of airborne survey systems in performing line measurements over land and water at various altitudes. The cumulative test results, together with the results of appropriate common engineering tests will permit an estimate to be made of the degree to which the airborne survey equipment under test meets military requirements as expressed in applicable QMR, SDR, TC, or other appropriate documents.

The specific tests to be performed, along with their intended objectives, are listed below:

a. Tests pertaining to type 1 commodities as defined in paragraph 2

1) Geodetic survey accuracy - The objective of this subtest is to obtain information on the system's distance-measuring accuracy and consistency.
2) Overwater survey accuracy - The objective of this subtest is to investigate the effects of multipath propagation on system's survey accuracy.
3) Repeatability - The objective of this subtest is to obtain a measure of the repeatability of system range measurements through a series of multialtitude line crossings.
4) Evaluation of System Controlled photography - The objective of this subtest is to investigate the capability of the system to perform controlled photography missions.

b. Tests pertaining to type 2 commodities as defined in paragraph 2

1) Traverse accuracy - The objective of this subtest is to obtain information on the systems position-determination accuracy by measurement of the closure error in a closed traverse survey.

5.1.2 Common Engineering Tests

Not included in this MTP are the following Common Engineering Tests which are applicable to these commodities:

a. MTP 6-2-500, Physical Characteristics
b. MTP 6-2-502, Human Factors Engineering
c. MTP 6-2-503, Reliability
d. MTP 6-2-504, Maintenance/Maintainability
e. MTP 6-2-507, Safety
f. MTP 6-2-508, Electromagnetic Vulnerability
g. MTP 6-2-509, Electromagnetic Compatibility
h. MTP 6-2-514, Electrical Power Requirements
i. MTP 6-2-515, Transmitter Range Tests
j. MTP 6-2-517, Frequency Accuracy and Stability
k. MTP 6-2-530, Altitude and Temperature Altitude Tests
l. MTP 6-2-531, Temperature Test
m. MTP 6-2-532, Sunshine Test
n. MTP 6-2-533, Rain Test
o. MTP 6-2-534, Humidity Test
p. MTP 6-2-535, Fungus Test
q. MTP 6-2-536, Salt Fog Test
r. MTP 6-2-537, Dust Test
s. MTP 6-2-538, Explosive Atmosphere Test
t. MTP 6-2-539, Immersion Test
u. MTP 6-2-540, Vibration Test
v. MTP 6-2-541, Shock Test

5.2 LIMITATIONS

This materiel test procedure is confined to overall system tests of test item mission accuracies including:

a. Electronic surveying (geodetic)
b. Controlled photography
c. Connection surveying (closed traverse)

Testing of individual subsystems and equipments which comprise the airborne survey system is covered by separate commodity MTP's.

6. PROCEDURES

6.1 PREPARATION FOR TEST

a. Select test equipment ideally having an accuracy of at least ten orders of magnitude greater than that afforded by the item under test, that is in keeping with the state-of-the-art, and whose calibration is certified in accordance with Department of the Army Regulations to assure traceability to the National Bureau of Standards.

b. Record the following information:

1) Nomenclature, serial number(s), manufacturer's name, and function of the item(s) under test.
2) Nomenclature, serial number, accuracy tolerance, calibration requirements, and last date calibrated of the test equipment selected for the tests.

c. Ensure that all test personnel are familiar with the required technical and operational characteristics of the item under test, such as stipulated in Qualitative Materiel Requirements (QMR), Small Development Requirements (SDR), and Technical Characteristics (TC).

d. Review all instructional material issued with the test item by the manufacturer, contractor, or government, as well as reports of previous tests conducted on the same types of equipment, and familiarize all test personnel with the contents of such documents. These documents shall be kept readily available for reference.

e. Prepare the necessary software for reduction of field data and prepare record forms for systematic entry of data, chronology of test, and analysis in final evaluation of the test item.

f. Prepare adequate safety precautions to provide safety for personnel and equipment, and ensure that all safety SOP's are observed throughout the test and that the item has successfully completed the examination prescribed in MTP 6-2-507, Safety.

g. Thoroughly inspect the test item for obvious physical and electrical defects. All defects shall be noted and corrected before proceeding with the tests. Verify correct power source, necessary test instrumentation, and inter-connection cabling. Perform such preliminary checks and alignment procedures as necessary to ensure, insofar as possible, that the test item represents an average equipment in normal operating condition.

h. Ensure that all support aircraft are properly instrumented as required, that arrangements for supporting and participating agencies, activities and facilities have been made, and that authorization for electromagnetic radiation at specific frequencies, power levels, and modulations for the required periods has been obtained.

i. Coordinate with the Meteorological Support Activity to ensure that meteorological information is obtained, as required, during all periods of operation. Frequency at which the observations are to be repeated shall be as mutually agreed upon between the test engineer and the support activity.

6.2 TEST CONDUCT

NOTE:

1. In order to maintain standardized test conditions and thereby allow a more comprehensive comparison between test results of like test items, the operational and computational procedures for geodetic surveys contained herein are patterned after those developed by the Air Force HIRAN mapping groups. The flight test program is accordingly recommended to be conducted over the test area indicated in Figure 1. The six ground stations comprising the Arizona-Nevada trilateration network shall be set up over United States Coast and Geodetic Service survey monuments whose approximate coordinates are listed in Table 1.
2. The trilateration network is designed to yield optimum information on test item distance measuring consistency. Four sliver triangles are incorporated in the network to assist in providing a strong determination of any constant error. The sliver triangles involve 9 of the 15 lines in

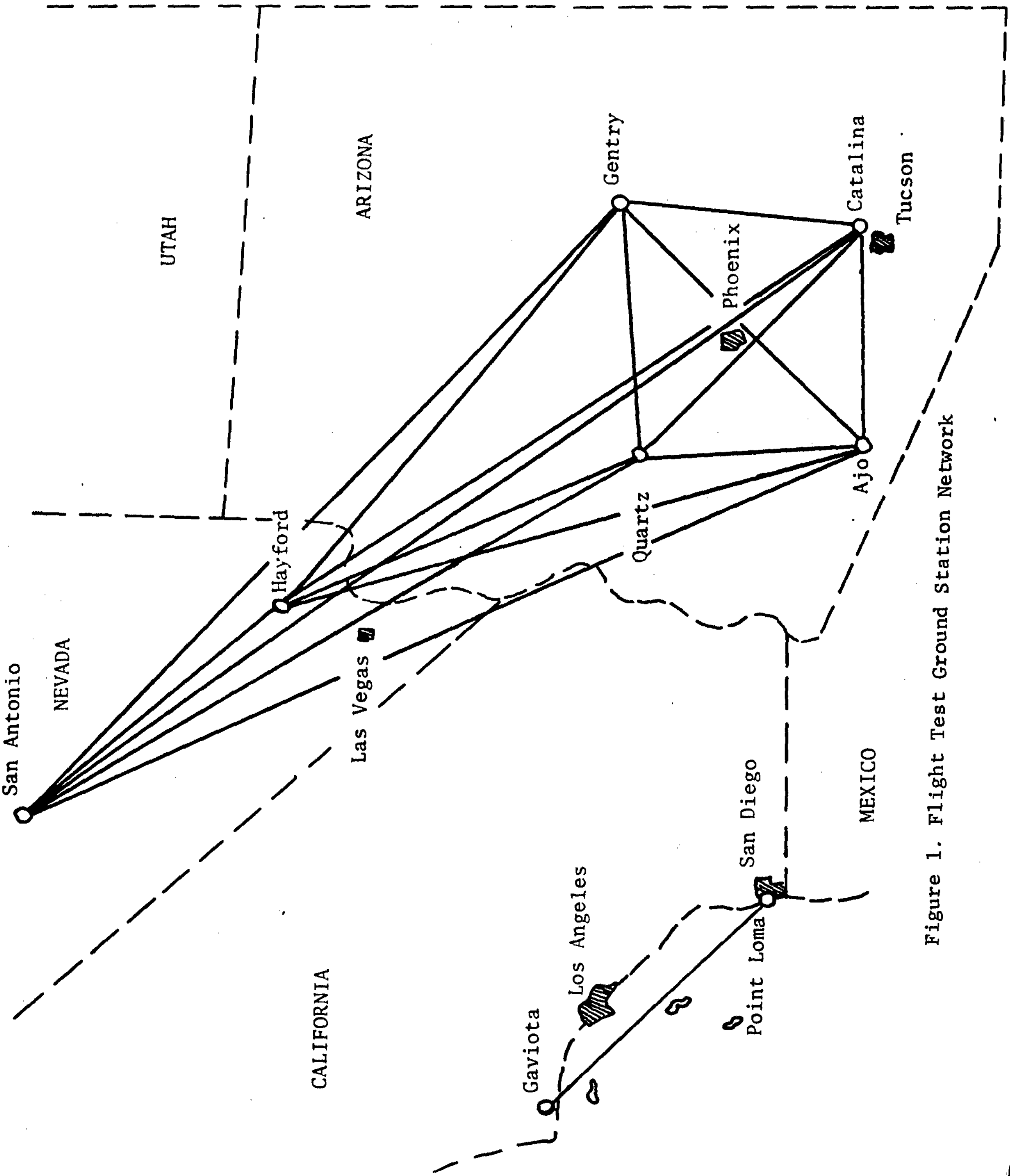

Figure 1. Flight Test Ground Station Network

the network and include the 4 approximately co-linear stations: Catalina, Quartz, Hayford, and San Antonio.

3. The ground station sites selected for the overwater tests are stations Point Loma in the vicinity of San Diego, and Gaviota in the vicinity of Santa Barbara.
4. Prior to testing, the trilateration network shall be evaluated for internal consistency by measurement and application of standard geodetic line differential formulae. Adjustments and/or statistical allowances shall be made accordingly.

TABLE 1

Approximate Geodetic Position of Test Ground Stations

	Approximate Position	
Station	Longitude	Latitude
Gentry	110° 42' 45"	34° 18' 05"
Catalina	110° 47' 16"	32° 26' 34"
Ajo	112° 50' 31"	32° 19' 24"
Quartz	112° 56' 07"	33° 55' 27"
Hayford	115° 11' 59"	36° 39' 27"
San Antonio	117° 14' 31"	38° 18' 31"
Gaviota	120° 11' 52"	34° 30' 06"
Point Loma	117° 14' 27"	32° 40' 22"

6.2.1 Geodetic Survey Accuracy

a. Consult pertinent operations procedures developed for use with the test item and prepare flight plans to perform a series of line crossing missions so as to traverse each line of the trilateration network exemplified in Figure 1.

b. Direct the aircraft containing the system under test to fly the test course maintaining the specified flight profile for determining geodetic line lengths.

c. Sequentially interrogate ground stations to derive ranging information in accordance with established procedures.

d. Record the following:

1) Airborne profile recorder output.
2) Range, time, and mission identification (on magnetic tape, computer-compatible format).

3) Meteorological observations.

6.2.2 Overwater Survey Accuracy

a. Consult pertinent operations procedures developed for use with the test item and prepare flight plans to perform a series of line crossing missions so as to allow repeat measurement of the overwater (Gaviota-Point Loma) line over widely varying geometries.

b. Direct the aircraft containing the system under test to fly the test course maintaining the specified flight profile.

c. Perform ranging measurements during the line crossing missions at 2000 foot intervals from the minimum specified altitude (approximately 4000 feet) to the maximum specified altitude (approximately 33,000 feet).

d. Record the following:

1) Airborne profile recorder output.
2) Range, time, and mission identification (magnetic tape, computer-compatible format).
3) Meteorological observations (in general, the atmospheric index of refraction profile shall constitute the minimum requisite data).

6.2.3 Repeatability

a. Prepare flight plans to perform a series of line crossing missions so as to traverse each line of a trilateration network which crosses over rocky and mountainous terrain.

NOTE: The Ajo-Catalina line provides sufficient orographic features to yield the desired variance.

b. Direct the aircraft containing the system under test to fly the test course maintaining the specified flight profile.

c. Perform ranging measurements during the line crossing missions at 2000 foot intervals from the minimum specified altitude to the maximum specified altitude (commensurate with terrain safety margin).

d. Record the following:

1) Airborne profile recorder output.
2) Range, time and mission identification (on magnetic tape in a computer-compatible format).
3) Meteorological observations.

6.2.4 Evaluation of System Controlled Photography

a. Consult pertinent operations procedures developed for use with the test system and prepare flight plans to provide a cloverleaf flight pattern with the point to be positioned located beneath the center of the pattern. The point to be positioned shall consist of a prominent landmark or other equally identifiable feature, and the pattern shall provide for four cardinal flight lines to be flown over the point.

b. Direct the aircraft containing the system under test to fly the test course, maintaining the specified flight profile, at a flight altitude and velocity commensurate with ground station signal reception and camera capabilities.

c. Obtain a minimum of 52 photographs of the known point, each controlled by system measured distances, using the following criterion:

1) 13 such photographs shall be made during each of the 4 cardinal flight lines: 6 as the aircraft approaches the point, 1 directly over the point, and 6 after passing the point.
2) Exposure interval shall be kept as short as possible to obtain the maximum number of photographs which contain the point.

d. In addition to the system controlled photographs of the known point, record the following:

1) Airborne profile recorder output.
2) Range, time, and mission identification (on magnetic tape, in a computer-compatible format).
3) Meteorological observations.

6.2.5 Traverse Accuracy

a. Prepare a closed traverse test course of a length commensurate with the capabilities of the test item. Ground truth for traverse stations will be established through conventional survey methods whose accuracy exceeds that of the test item in accordance with paragraph 6.1.a.

b. Instruct the vehicle crew to traverse the test course relying solely on the test item and traverse map for navigation. The crew shall mark the indicated location of each traverse station (north, east, and elevation plus directional readings).

c. Survey the indicated traverse station locations and determine the three dimensional error with respect to ground truth.

d. A sufficient number of test replications shall be accomplished in order to achieve statistical confidence in the resultant data.

6.3 TEST DATA

6.3.1 Preparation for Test

Data to be recorded prior to testing shall include but not be limited to:

a. Nomenclature, serial number(s), manufacturer's name, and function of the item(s) under test.

b. Nomenclature, serial number, accuracy tolerances, calibration requirements, and last date calibrated of the test equipment selected for the tests.

c. Damages to the test item incurred during transit and/or manufacturing.

6.3.2 <u>Test Conduct</u>

Data to be recorded in addition to specific instructions listed below for each sub-test shall include:

a. A block diagram of the test setup employed in each specified test. The block diagram shall identify by model and serial number, all test equipment and interconnections (cable lengths, connectors, attenuators, etc.) and indicate control and dial settings where necessary.

b. Photographs or motion pictures (black and white or color), sketches, charts, graphs, or other pictorial or graphic presentation which will support test results or conclusions.

c. An engineering logbook containing, in chronological order, pertinent remarks and observations which would aid in a subsequent analysis of the test data. This information may consist of temperatures, humidity, pressures, and other appropriate environmental data, or other description of equipment or mathematical calculations, test conditions, intermittent or catastrophic failures, test parameters, etc., that were obtained during test.

d. Test item sample size (number of measurement repetitions).

e. Instrumentation or measurement system mean error stated accuracy.

6.3.2.1 Geodetic Survey Accuracy

Geodetic survey accuracy test data to be recorded shall include:

a. Airborne profile recorder output
b. Range, time, and mission identification
c. Meteorological observations

6.3.2.2 Overwater Survey Accuracy

Overwater survey accuracy test data to be recorded shall be the same as that delineated in paragraph 6.3.2.1.

6.3.2.3 Repeatability

Repeatability test data to be recorded shall be the same as that delineated in paragraph 6.3.2.1.

6.3.2.4 Evaluation of System Controlled Photography

System controlled photography test data to be recorded shall be the same as that delineated in paragraph 6.3.2.1 in addition to the system controlled photographs of the known point.

6.3.2.5 Traverse Accuracy

Traverse accuracy test data to be recorded shall include:

a. Northing, Easting and Elevation Errors for each traverse station
b. Three dimensional traverse closure error plus directional error

6.4 DATA REDUCTION AND PRESENTATION

Processing of raw test data shall, in general, consist of organizing, marking for correlation and identification, and grouping the test data according to sub-test title. Test criteria or test item specifications shall be noted on the test data presentation to facilitate analysis and comparison.

Specific instructions for the reduction and presentation of individual sub-test data are outlined in the succeeding paragraphs.

6.4.1 Geodetic Survey Accuracy

The geodetic survey accuracy test results shall be reduced to measured line lengths of each line of the trilateration network. A suggested final data presentation form is indicated in Table 2.

TABLE 2

Airborne Survey System - Geodetic Distance Comparison

LINE	SYSTEM (N. Miles)	GEODETIC (N. Miles)	$S-G \times 10^4$ (N. Miles)
Catalina-Gentry			
Ajo-Gentry			
Ajo-Catalina			
Quartz-Gentry			
Quartz-Ajo			
Hayford-Gentry			
Hayford-Ajo			
Hayford-Quartz			
Antonio-Gentry			
Antonio-Catalina			
Antonio-Ajo			
Antonio-Quartz			
Antonio-Hayford			

$$PE_s = 0.6745 \sqrt{\frac{\Sigma X^2}{N}} \qquad \text{Mean} = \underline{\qquad}$$

$$PE_s = \pm \underline{\qquad\qquad} \text{ N. Miles}$$

$$X = (S-G)$$

The probability of error of a single observation shall be computed in accordance with the given formula and the data analyzed to determine:

a. The mean difference and signs of the errors.
b. The existence of possible systematic or constant error.
c. The source of errors not necessarily in the system under test such as:

1) Index of refraction errors.
2) Altitude errors causing horizontal errors as a function of range.
3) Computational errors (round off, etc.).

6.4.2 Overwater Survey Accuracy

Overwater survey accuracy test data shall be reduced and presented in the general manner indicated in Table 3. Additional statistical inferences shall be drawn from the test data as necessary or as indicated by test criteria. As in the geodetic survey accuracy test, the test results shall be analyzed for errors with emphasis on measurement errors that could be attributed to multipath phenomena.

TABLE 3

Results of Overwater Tests

ALTITUDE (feet)	SYSTEM MEASURED (SM) N. Miles	V = SM-Mean SM ($X\ 10^4$) N. Miles

Mean System Measured Distance = ____________ N. Miles.

Geodetic Distance = ____________ N. Miles

$PE_s = \pm$ ____________ N. Miles

6.4.3 Repeatability

Repeatability test results shall be reduced and presented in the manner described in paragraph 6.4.2.

6.4.4 Evaluation of System Controlled Photography

The evaluation of the capability of the system to perform controlled photography missions shall be accomplished in three stages:

a. Photogrammetric determination of photo nadirs shall be accomplished and their quality analyzed.

b. System nadirs for each photograph shall be determined and the data quality analyzed.

c. The overall nadir accuracy shall be evaluated with respect to ground truth to arrive at:

1) Tilt error values
2) Northing - easting errors

Statistical methods of data reduction shall be employed as necessary to arrive at confidence intervals or other measures of system performance as expressed in the applicable test criteria.

6.4.5 Traverse Error

a. Traverse closure errors shall be subjected to statistical analysis for comparison with test criteria. The criterion of accuracy commonly employed in two-dimensional errors is the Circular Probable Error (CPE) which is defined as the radius of a circle centered such that on the average 50 percent of the errors may be within the circle. Statistical analysis shall also be applied to determine the normality of the error distribution.

b. Heading errors at each traverse station shall be determined by comparison of recorded data to ground truth. Statistical reduction of azimuth error data shall be accomplished as in a. above where indicated by test directive or criteria.

c. Elevation errors shall be cataloged and analyzed in a like manner.

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13. ABSTRACT

This Engineering Test Procedure describes test methods and techniques for evaluating the technical performance and characteristics of Tactical Airborne Survey Systems related to the criteria expressed in applicable Qualitative Materiel Requirements (QMR), Small Development Requirements (SDR), Technical Characteristics (TC), or other appropriate design requirements and specifications. The test methods provide for empirical determination of performance and characteristics of airborne survey systems in performing live measurements over land and water at various altitudes.

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